Mechanical and Clinical Rationale of Prototype Bone Reduction Forceps

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Objective: To describe the mechanical rationale and clinical application of prototype right-angle reduction forceps.

Methods: A pair of prototype right-angle reduction forceps was designed and manufactured specifically to improve the consistency and ease of fracture reduction. It was used to reduce mandible fractures of the mandible body, parasymphysis, and symphysis in 4 patients. The fractures ranged from minimally displaced to comminuted and displaced fractures.

Results: The pilot monocortical holes used for insertion of the right-angle reduction forceps into the mandible were easier to drill than the old method of drilling angled holes for standard reduction forceps. The older method required constant guesswork as to the correct angle of the hole relative to the tines of the curved reduction forceps. The right-angle reduction forceps required no guesswork because the pilot hole is drilled at a right angle to the surface of the outer bone cortex and at more than 1 cm laterally on each side of the fracture line. There were no episodes of outer cortical bone avulsion or any necessity for re-drilling new pilot holes. These forceps provided sufficient force for excellent reduction of the fracture edges. The design also provided improved access for plating superior and inferior to its shaft while it was engaged.

Conclusions: Although curved bony reduction forceps are standard in most mandibular plating sets, they provide less predictable and efficient reduction of fractures than the right-angle reduction forceps. Prototype reduction forceps require little to no additional training to use properly.

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The mandible is the second most commonly fractured bone within the face.1 The etiology of most mandibular fractures is mechanical trauma associated with vehicular accidents or assault.2 The mandibular areas most commonly fractured include the body (29%), condylar-subcondylar region (26%), angle (25%), and the symphysis region (17%).3

The treatment goal of mandible fractures is to restore premorbid occlusion and function and to prevent infection. Proper alignment and reduction are important for mastication, speech, and normal range of oral motion. Reduction gaps of more than 1 mm between fracture segments result in secondary healing, which results in callus formation and increases the risk of a nonunion. Direct bone contact between the fracture segments promotes primary bone healing, which leads to earlier bone regrowth and stability across the fracture site. Occlusive displacement of less than 1 mm can be detected by the patient.

Studies have shown that open reduction with compression of fracture lines increases bony surface contact, leading to increased stability and the promotion of healing.4,5 Clinical experience shows that fractures that are not adequately reduced are at higher risk for malunion and infection leading to further patient morbidity. In an effort to improve approximation and contact of fracture segments, bone reduction forceps are often used.

Various models of bone reduction forceps are largely based on modifications of the towel clamp (Figure 1).6 These traditional reduction forceps are applied by drilling engagement holes on either side of the fracture line; the tines of the towel clamp–type reduction forceps are inserted, and the clamp is tightened to reduce the fracture. The towel clamp type of reduction forceps frequently require multiple trials with drilling adequate engagement holes for the tines. Because the ends of the forceps are at an acute angle relative to the bone surface, the engagement holes that are drilled must be complimenterly angled. The angles of the engagement holes and the distance from the fracture line are estimated by the surgeon, which can lead to placement of suboptimal engagement holes. Furthermore, the angled holes are susceptible to acci-
dental avulsion or chipping of the outer bone cortex at the engagement holes with tightening of the forceps. This may require further drilling of additional holes in a trial and error process (Figure 2A).

The method of open reduction of symphyseal, para-symphyseal, and body fractures using prototype right-angle reduction forceps is described herein. Right-angle forceps are easily applied and reliable. In addition, they allow the surgeon to apply hardware superior and inferior to the raised profile of the right-angle tines while the forceps are engaged and the fracture is reduced. These prototype forceps eliminate trial and error problems that are typically associated with the modified towel clamp type of reduction forceps. A clinical case presented herein illustrates the use of the forceps and describes potential benefits of this method.

**METHODS**

The use of clamps to reduce a fracture line is not a new concept. Current reduction forceps are a towel clamp or modification thereof (Figure 2). The senior author (M.S.K.) helped to develop prototype reduction forceps that differ from the towel clamp in that the tines are at a right angle (Figure 3).

These forceps were used clinically to reduce mandible fractures of the mandible body, parasympysis, and symphysis in 4 patients. The fractures included minimally displaced, comminuted, and displaced fractures. The forceps provided sufficient force for reduction of the fracture edges. There were no episodes of outer cortical bone chipping or any necessity for redrilling engagement holes, which commonly occur with the towel clamp reduction forceps that are standard in most mandibular plating sets. The 4 patients had excellent reduction and occlusion. None of the patients experienced hardware failure or infection, or required reoperation at their 6-month follow-up.

A 32-year-old patient presented with a left para-symphyseal and left subcondylar fracture (Figure 4A). Informed consent was obtained for maxillomandibular fixation and open reduction of the parasympysisal fracture. The patient was taken to the operating room, where anesthesia was induced via nasotracheal intubation. Arch bars were placed on the maxillary and mandibular teeth using 24-gauge wire, and interdental fixation was achieved with rubber bands. A sublabial incision was performed, and a Freer elevator was used to expose the parasympysisal mandible fracture (Figure 4B). Two monocortical holes were then drilled approximately 1.2 cm lateral to the fracture line midway down the vertical height of the mandible (Figure 4C). The tines of the right-angle reduction forceps were placed within the holes and tightened (Figure 4D), and a 2.0 tension band was placed across the superior aspect of the fracture line (Figure 4E). Two bicortical holes were drilled across the inferior aspect of the fracture, and a 2.4 locking plate was appropriately screwed in place (Figure 4F). Figure 4G shows the reduced fracture with the tension band and locking plate in place.

The patient was discharged after overnight observation, and a liquid diet was prescribed while intermaxillary fixation was in place. Normal occlusion was achieved when the patient was examined at the 2-week and 3-month follow-ups.

**COMMENT**

In 1978, Champy et al described the use of miniature and malleable screwed plates as a means of open reduction of
mandible fractures. Their study comprised 183 patients who had undergone monocortical plate fixation and who were followed up for 5 years. This work illustrates the advantages of open reduction with plating systems over transosseous wiring. Champy et al. showed that their surgical approach was simpler and resulted in less scarring. There were fewer wound complications, such as infection or dehiscence. Fewer patients required postoperative dental correction. Patients were able to have a soft diet by the first postoperative day and were shown to have less pain overall. This study helped to establish plate and screw fixation as a proven technique.

Compression during plate fixation has been shown to aid in the stability and healing process of a fracture site. The primary mechanism is thought to be due to increased contact of bony surfaces. Reduction forceps can hold large segments of bone together to increase surface contact while plate fixation is performed. An additional benefit of using reduction forceps is that plating of body fractures can be achieved by a single operating surgeon because the forceps hold the fracture in reduction while the plates and screws are placed.

Studies by Choi et al. using silicon mandibular models have established the optimum position of the modified towel clamp–type reduction forceps relative to symphyseal and parasymphyseal fractures. Fractured models were reduced at 3 different horizontal levels: midway bisecting the mandible, 5 mm above midway, and 5 mm below midway. In addition, engagement holes were tested at distances of 10, 12, 14, and 16 mm from the fracture line. The models were subjected to heating up to 130°C for 100 minutes and then were cooled to room temperature. Stress patterns were then evaluated using a polariscope. Optimal stress patterns (defined as those distributed over the entire fracture site) were noted when the reduction forceps were placed at the midway or 5 mm below midway and at least 12 mm from the fracture line for symphyseal or parasymphyseal fractures and at least 16 mm for mandibular body fractures. The greater optimal distance from the fracture line for the engagement holes in the case of body fractures is most likely due to the presence of thinner bone in the body. It is important to note that the reduction forceps used in the study by Choi et al. were a curved modified towel clamp forceps, in which the tips of the forceps tines end up more closely approximated than the outer cortical entry point. Therefore, the optimal site for engagement holes of no more than 12 to 16 mm from the fracture line, as recommended by Choi et al., does not apply to the right-angle reduction forceps. However, one can infer that the optimal site for engagement holes with the right-angle reduction forceps would be no more than 16 mm from the fracture line, whereas the minimal optimal distance for engagement holes with the right-angle reduction forceps should likely be no less than 7 mm from the fracture site (12 mm minus the length of curved portion of
a modified towel clamp reduction forceps). We have used a distance of approximately 12 mm from the fracture line in symphyseal or parasymphyseal and body fractures with the right-angle reduction forceps without problems. The presence of increased bone area between the apposing tines with the right-angle reduction forceps compared with that between the apposing tines of the curved towel clamp–type forceps provides a better purchase and resistance to the compressive forces of the tines.

Development of prototype right-angle reduction forceps have eliminated many of the problems encountered when using the modified towel clamp for fractures of the mandibular body. These forceps are applied by drilling engagement holes perpendicular to the outer cortex. These perpendicular engagement holes are easily drilled at a distance of 1.2 cm from the fracture line and at or below the midway portion of the mandibular body (Figure 2B). This minimizes the problems of bone chipping and trial and error drilling often encountered with the towel clamp. An additional advantage of the right-angle reduction forceps is that one surgeon can apply both the upper and lower plates without adjusting the forceps (Figure 4E and Figure 4F).

When using the right-angle reduction forceps, there was no need to redrill engagement holes, and optimal surgical results were obtained in all cases. The use of these forceps could be extended to other head and neck surgical procedures in which bone reduction is required.

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REFERENCES